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RESPONSE OF WHEAT, CANOLA AND ALFALFA TO SIMULATED ACIDIC PRECIPITATION[1]

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Abstract. Wheat, canola and alfalfa were subjected to simulated acidic precipitation with pH ranging from 5.6 to 2.6 under controlled growth room conditions. In this short-term experiment, wheat, canola and alfalfa do not appear to be sensitive to the simulated acid rain treatments used. Wheat and canola showed no visible symptoms of injury with any of the treatments. The pH 2.6 resulted in whitish spots on alfalfa leaflets. The economic yield was not affected at any of the acidity levels used in this study. Dry weight of the aboveground vegetative parts of wheat and canola was stimulated by the most acidic treatment (pH 2.6), apparently as a result of the higher nutrient content of the simulated acidic rain. Although belowground biomass for any of the species tested was not affected by rain acidity, the shoot : root ratio was significantly higher at pH 2.6 than with the control.

Chlorophyll a concentration in alfalfa leaves was reduced at only the highest acidity treatment. Chlorophyll b was not affected. While potassium levels in alfalfa leaves was significantly reduced at pH 2.6, no change in the concentration of Ca, Mg and P was noted. Sulfur and nitrogen concentrations increased, mainly at pH 2.6, reflecting the composition of the simulated rain solution.

1. Introduction

Acidification of precipitation as a result of anthropogenic, acid forming emissions has been reported in many areas of the world, including eastern Canada. Damage to vegetation and reduction in forest productivity in those areas have been attributed to the acidified precipitation (e.g., Jonsson, 1977; Binns and Redfern, 1983). Although, presently, no severe precipitation acidification problems have been identified in most areas of the Canadian Prairie Provinces, the issue is of growing concern in view of future expansion in the tar sand region of Alberta and the heavy oil region of Saskatchewan and Alberta (Shewchuk, 1982).

Several reports on the response of vascular plants to acidic deposition have appeared in the literature in recent years (e.g.

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Jacobson, 1980; Lee and Weber, 1979; Haines et al., 1980; Shriner, 1980; Raynal et al., 1982; Percy, 1983). However, most of those studies have dealt with European or eastern North American plant species. None of the major Canadian field crops or forage plants has been studied with regard to their sensitivity to acidic precipitation. In this study, the response of wheat, canola and alfalfa to simulated acidic precipitation was investigated under controlled growth room conditions.

2. Materials and Methods

Neepawa wheat, Rambler alfalfa (treated with Thiram for verticilium wilt), and Regent canola were used in this growth room experiment. Seeds were planted in 13 cm pots containing a medium consisting of soil, peat moss and vermiculite at a ratio of 2:1:1 on a volume basis, respectively. The soil used was a sandy loam obtained from the Saskatoon area, Saskatchewan (Table I). Simulated rain solutions were prepared using the same procedures described by Abouguendia and Baschak (1987). The major ion concentrations of the background (control) rain simulant were in the range reported for precipitation at the Cree Lake CANSAP (Canadian Network for Sampling Precipitation) station located 580 km north of Saskatoon. The pH of the background rain simulant was adjusted to the required treatment level by addition of sulfuric and nitric acids (ratio of 2:1). The following treatments were included: (a) pH 5.6, 2.5 μeq L^{-1} H^+ control); (b) pH 4.6, 25 μeq L^{-1} H^+; pH 3.6, 250 μeq L^{-1} H^+; and pH 2.6, 2500 μeq L^{-1} H^+.

Standard line, low-flow, full-cone nozzles (Series WL, 303 stainless steel, Beta Fog Ltd.) were mounted in specially designed simulated acid rain application chambers (Figure I) (Abouguendia and

Baschak; 1985 and Abouguendia et al, 1986). The study was carried out during the period October 22, 1985 - May 12, 1986.

A completely randomized experimental design with 20 replicates was used. Treatments were applied weekly starting four weeks from seeding. Treatments of the two field crops continued until maturity, receiving 10 and 12 applications for canola and wheat, respectively. Alfalfa received 21 applications. The average application rate per event was approximately 9mm of simulated rain applied over a 30 minute period.

Initial growth room day temperature was 22±1°C. This was increased gradually to 26±1°C at the end of the experiment. Night temperature was 17±1°C. Initial photoperiod was 12 hours and was increased gradually to 14 hours at the end of the experiment. Light intensity was approximately 160 mol $m^{-2}s^{-1}$.

Notes on the occurrence of visual symptoms of damage were obtained. Alfalfa leaves were collected for foliar nutrient analysis and chlorophyll determination, while wheat and canola were harvested for biomass determination. Belowground biomass was extracted by soaking the soil material from the experimental pots in water and manually agitating the root mass until the soil was washed off the roots. Then the material was transferred to a no. 12 sieve (1.68 mm opening) for further washing and for removal of peat moss and other foreign material. Plant material was oven-dried for 48 hours at 60°C. Foliar analysis was carried out using the methods indicated in Table II.

Data were subjected to analysis of variance, then Duncan's Multiple Range Test, where appropriate.

3. Results and Discussions

3.1 Visible Foliar Injury

Wheat and canola showed no visible symptoms of injury from any of the acid rain treatments. However, whitish spots were observed on alfalfa leaflets (Table III). The survey of damage was made on two occasions, December 1985 and January 20, 1986. On both dates, only pH 2.6 caused significant visible injury (Table III).

3.2 Aboveground Biomass

The aboveground biomass of alfalfa was not affected by any of the acid rain treatments (Table IV). It appears that in the short term, the detrimental effects of high acidity have been masked by a fertilization effect resulting from the added nutrients in the simulated acid rain. These results agree with the findings of Evans et al. (1982) who found no reduction in biomass of alfalfa after 57 simulated rain events of pH 2.7 over a period of 105 days. Rebbeck and Brennan (1984) reported similar results using pH of 3.0. Cohen et al (1981) indicated increased yield at pH 4.0 and 3.5, but no effects at pH 3.0.

The weight of canola foliage appeared to have been stimulated by the most acidic treatment (Table V). However, seed yield was not affected. Aboveground biomass of wheat was stimulated by pH 2.6 (Table VI). As with canola, this was not reflected in any increase in grain yield.

3.3 Belowground Biomass

The belowground biomass of the species studied was not affected by the increased rain acidity (Table VIII). The shoot : root weight ratio

remained constant with the exception of wheat where a large increase in the ratio was recorded at pH 2.6 (Table VIII). While very few studies dealt with the effects of acidic precipitation on belowground biomass, our results generally compare well with Cohen et al. (1981) who reported a reduction in root growth of wheat at pH 4.0 or lower. Lee et al. (1981) indicated and increase in the shoot : root ratio for alfalfa. Only a slight increase in this ratio for alfalfa was noted with increasing acidity.

3.4 Alfalfa Leaf Analysis

The concentration of the following nutrients in alfalfa leaves was determined at the end of the experiment: calcium, potassium, magnesium, nitrogen, and sulfur (Table IX). The results showed a statistically significant increase in the concentration of sulfur in the leaves at pH 3.6 and 2.6. Nitrogen levels were significantly higher at pH 2.6 than in the control. Potassium concentration decreased significantly with the pH 2.6 treatment.

Nutrient leaching from foliage has been shown to increase with acidic precipitation (Hindawi et al., 1980; Evans et al., 1982). In this study only potassium showed a decline with acidity. This could be due to an accelerated uptake of nutrients by plants from the available nutrient pool in the soil (Abouguendia et al., 1986) which would compensate for the losses caused by leaching. In the long term, however, the level of available nutrients will be reduced. The increase in nitrogen and sulfur concentration noted in this study reflect their high concentration in the simulated rain solutions.

Chlorophyll a and b were determined on foliage samples of alfalfa (Table IX). Rain acidity had no significant effect on chlorophyll b concentration in alfalfa leaves. However, chlorophyll a concentration was reduced significantly with the pH 2.6 rain treatment. This reduction of chlorophyll a, however, was not accompanied by a reduction in yield as indicated above.

4. Summary and Conclusions

In the short term, wheat, canola and alfalfa do not appear to be sensitive to simulated acid rain with pH ranging from 5.6 to 2.6 applied under controlled growth room conditions. Wheat and canola showed no visible symptoms of injury with any of the treatments. The pH 2.6 resulted in whitish spots on alfalfa leaflets. The economic yield was not affected at any of the acidity levels used in this study. Dry weight of the aboveground vegetative parts of wheat and canola increased with the most acidic treatment (pH 2.6), apparently as a result of the higher nutrient content of the simulated acidic rain. Although belowground biomass for any of the species tested was not affected by rain acidity, shoot : root ratio was significantly higher at pH 2.6 than with control.

Chlorophyll a concentration in alfalfa leaves was reduced at only the highest acidity treatment. Chlorophyll b was not affected. While potassium levels in alfalfa leaves were significantly reduced at pH 2.6, no change in the concentration of Ca, Mg and P was noted. Sulfur and nitrogen concentrations increased, mainly at pH 2.6, reflecting the composition of the simulated rain solution.

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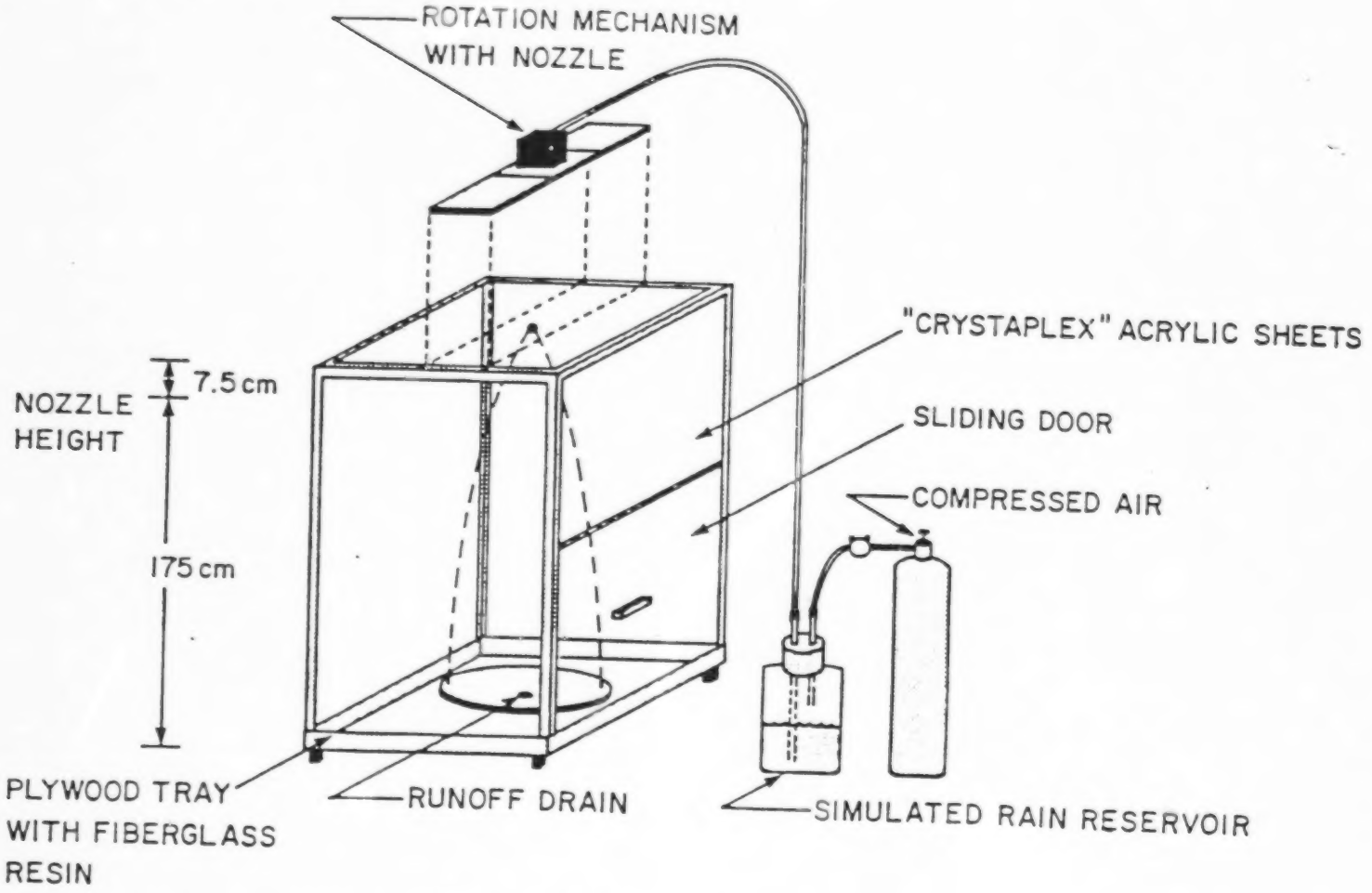

Figure 3.1 Detail of Treatment Chamber and Simulated Rain Dispensing System.

TABLE I
Characteristics of the Soil Used in the Experiments.

Parameter	Agricultural Soil
NO_3-N (ppm)	33
P (ppm)	16
K (ppm)	425
E. Conductivity (mS cm^{-1})	1.9
pH	6.4
Saturation (%)	50

TABLE II

Procedures Used in Foliar Analyses.

Parameter	Procedure
Total N	Kjeldahl
Total P	Colorimetric
K	Flame photometry
Total S	Bromine/perchloric gravimetric
Ca	Nitric/perchloric atomic absorption
Mg	Nitric/perchloric atomic absorption
Chlorophyll	Knudson (1977)

TABLE III

Number of Alfalfa Leaflets (per pot) with Visible Symptoms of Injury. (Values are means of 20 samples followed by standard deviations in brackets).

Treatment (pH)	December 19, 1985	January 20, 1986
5.6	0.05 (0.224)	0.20 (0.523)
4.6	0.05 (0.224)	0
3.6	0.1 (0.31)	0.05 (0.224)
2.6	3.05 (2.59)*	17.95 (12.59)*

*Significantly different from the control at the 0.05 level.

TABLE IV

Summary of the Aboveground Biomass (oven-dry basis) for Alfalfa. (Values are means (g) of 20 samples followed, in brackets, by standard deviation).

Treatment (pH)	Biomass
5.6	2.31 (0.5)
4.6	2.29 (0.53)
3.6	2.49 (0.78)
2.6	2.06 (0.42)

TABLE V

Summary of the Total Aboveground Biomass and Seed Weight (oven-dry basis) for Canola. (Values are means (g) of 20 samples followed, in brackets, by standard deviation).

Treatment (pH)	Total Biomass	Seed Weight (with capsules)
5.6	1.38 (0.23)	0.64 (0.19)
4.6	1.41 (0.21)	0.61 (0.19)
3.6	1.37 (0.24)	0.59 (0.23)
2.6	1.62 (0.4)*	0.72 (0.17)

*Significantly different from the control at the 0.05 level.

TABLE VI

Summary of the Total Aboveground Biomass and grain weight (oven-dry basis) for Wheat. (Values are means (g) of 20 samples followed, in brackets, by standard deviation).

Treatment (pH)	Total	Grain Weight
5.6	1.64 (0.19)	0.63 (0.16)
4.6	1.53 (0.17)	0.56 (0.12)
3.6	1.60 (0.15)	0.63 (0.14)
2.6	1.78 (0.25)*	0.63 (0.14)

*Significantly different from the control at the 0.05 level.

TABLE VII

Summary of the Belowground Biomass Data. (Values are means (g) of five samples and are followed, in brackets, by standard deviation).

Treatment (pH)	Alfalfa	Wheat	Canola
5.6	0.83 (0.26)	0.13 (0.04)	0.38 (0.07)
4.6	0.75 (2.14)	0.12 (0.03)	0.44 (0.06)
3.6	0.88 (0.29)	0.15 (0.1)	0.34 (0.08)
2.6	0.61 (0.14)	0.10 (0.03)	0.46 (0.07)

TABLE VIII

Shoot : Root Ratio for Canola, Wheat and Alfalfa.

Treatment (pH)	Canola	Wheat	Alfalfa
5.6	5	13	0.7
4.6	5	13	0.8
3.6	6	11	0.8
2.6	5	18	1.0

TABLE IX

Summary of the Foliage Nutrient Data (%) for Alfalfa. (Values are means of 10 samples and are followed in brackets by standard deviation).

Treatment (pH)	P	Ca	K	Mg	N	S
5.6	0.26 (0.025)	1.29 (0.137)	3.24 (0.74)	0.33 (0.06)	3.26 (0.172)	0.291 (0.067)
4.6	0.26 (0.044)	1.42 (0.87)	3.31 (0.53)	0.358 (0.059)	3.51 (0.277)	0.339 (0.060)
3.6	0.275 (0.034)	1.39 (0.197)	3.17 (0.68)	0.337 (0.044)	3.42 (0.466)	0.365 (0.038)*
2.6	0.27 (0.036)	1.40 (0.183)	2.36 (0.59)*	0.357 (0.051)	4.03 (0.469)*	0.356 (0.053)*

*Significantly different from the control at the 0.05 level.

TABLE X

Summary of the Chlorophyll Data. (Values are means (µg/mg) of 20 observations and are followed by standard deviation).

Treatment (pH)	Chlorophyll a	Chlorophyll b
5.6	3.24 (1.39)	1.02 (0.59)
4.6	3.53 (1.99)	1.16 (0.71)
3.6	2.68 (1.97)	0.64 (0.8)
2.6	1.98 (1.11)*	0.79 (0.55)

*Significantly different from the control at the 0.05 level.